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GIANT AIRPLANES.

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It is hardly possible for the most imaginative aeronautical enthusiast to look forward to a time when the airplane will have reached dimensions commensurate with those already attained by the airship. The lighter-than-air craft has inherent advantages, when enormous sizes are in view, which can hardly be counterbalanced by any technical skill that may be applied to the improvement of the heavier-than-air types. The most evident of these advantages is that the lift of an airship, depending on the volume of gas contained in the envelope, goes up in proportion to the cube of the dimensions, while the lift of the airplane, dependent on the area of the wings, varies only in proportion to the square of the dimensions. That is to say, doubling the length, span and all other dimensions would increase the lift of an airship eightfold, while the carrying power of the airplane under given conditions would be multiplied only by four. Since the weight of the airplane structure would go up more rapidly than the lift if the large and small airplanes were of the same type and constructed in the same way, it is evident that, in theory at least, there is a limiting size beyond which an airplane would be unable to lift its own weight, to say nothing of any useful load.

Notwithstanding this handicap, however, improvements in design practice and in the methods and materials of construction of heavier-than-air craft have been such that it has been possible to build and use them in sizes which were regarded as far beyond the

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bounds of practicality only a few years ago. In 1910, when aviation competitions were just beginning, one of the most distinguished of early aircraft constructors declared himself satisfied that it would never be possible to exceed a span of 100 feet with the type of airplane then known, yet the first crossing of the Atlantic by air was made with an airplane which exceeded by 25 per cent the limiting dimensions thus boldly laid down. The increase in size has been due in part to improvements in efficiency from an aerodynamic standpoint, but much more important factors have been the use of new structural arrangements and the giving of more careful attention to the efficient distribution of weight.

High Speed with Small Craft.

Before entering into a detailed technical discussion, the question naturally arises as to what the limits of size are, if any such limits really do exist. The largest airplanes that have been built and flown up to the present time have measured about 150 feet from tip to tip of the wings, while the total weight carried in flight has been in the neighborhood of 17 tons. As illustrating the breadth of the gap, already alluded to, between the maximum size of the airplane and that of the airship, it may be pointed out that a total lift of 70 tons is commonplace for a rigid airship. There is no reason, however, to set the limit on either type of aircraft at the point already attained, or indeed to impose a definite limit at any point whatever at the present time. It takes a bold man to set a marker in the path of progress

and say: "Thus far, no farther, shalt thou go," but it is at least possible to predict that further development in the direction of increased size is likely to be slow, both for technical and for economic reasons.

The giant airplane must find its field in commercial transport if its development on a large scale is to continue, and the patronage attracted by air transport enterprises at the present time is not sufficient to justify a search for larger units than those now available. In fact, one of the greatest merits of the airplane for high speed transportation is that the units are so small that even a moderate amount of traffic makes it possible to schedule frequent trips at short intervals and thus to avoid loss of time in waiting for a vehicle. In the past, on land and sea, increased speed has always meant increased size of unit. The fastest ships are the large ones, the fastest trains are drawn by specially powerful and heavy locomotives. In the airplane alone high speed is compatible with the use of small units, and this is an advantage which should not be lightly cast aside by seeking for larger airplanes at the present time. The giant airplane in commerce will undoubtedly come, for it has distinct advantages in reliability and in economy of operation, as well as in making it possible to offer the passengers comforts and conveniences prohibited by lack of space on the smaller types, but the giant airplane must wait on a public demand.

Nevertheless, while granting that development toward increased size cannot be unduly hastened, it is interesting to examine the

present technical status of the giant airplane and to see what limitations are set on the type of construction employed, and also to gather, if possible, an idea of the probable trend of the development of large heavier-than-air craft in the future.

Advantages in Great Size.

Large airplanes have three distinct advantages which go far to invalidate the theoretical limitations on the size attainable. First, and perhaps most fundamental, it is the rule in aeronautics as elsewhere in engineering practice that a large structure can be more efficiently built than a small one because the details can be worked out with greater refinement on a large scale. The structural efficiency of the Brooklyn Bridge is much greater than that of a footbridge spanning a brook because the design is more elaborate, but no one would think of attempting, because of that fact, to make a footbridge as a scale model of the structure which spans the East River. So complex a construction on so small a scale would be impracticable even if money were no object. The same rule holds true for the airplane. It may be practical to make the wing-spar in a single-passenger airplane only by cutting it from a single solid piece of wood, but the corresponding part for an airplane of large size can be built up of many pieces, each designed to take efficiently the stress falling on it.

The second of the advantages inherent in the large airplane is that, as already suggested, the weight can be better distributed than on a small one. Since the stresses in the wing structure of a

an airplane, the stresses which are ordinarily the critical factors in determining the limiting dimensions, are proportional to the load that has to be transmitted through the wings themselves, it is obviously advantageous to balance the up and down loads directly against each other as far as possible. The up load is the lift due to the air pressure, and is distributed nearly uniformly over the wing surface, while the down load is the weight of the structure itself and the attached loads. Direct balance can therefore be secured only by distributing some of the weight over the wings instead of concentrating it all in a central body.

This distribution is most easily carried out by separating the power plants in a multi-engined airplane, mounting them at intervals along the wings, and such a practice has been followed in most of the large airplanes built up to the present time. The separation of the power plants has a certain drawback, however, in that engines out on the wings are not likely to receive as close attention or as frequent inspection from a mechanic as they would if all grouped together in one place. Also, the use of a number of engines, uniformly spaced over a large part of the wing span, although ideal from the standpoint of the stresses in flight, is very bad in landing, the weight on the wings causing them to whip downward violently when the wheels touch the ground. It is hardly possible to distribute the wheel impact between more than four points, and the effect of a large concentrated load on the wings at a point where there is no direct connection from the wheels may be to break the wings off downward even in a comparatively gentle

landing. The arrangement of weight must, therefore, be a compromise between the ideal for flight and that for landing, and the plan usually adopted is to arrange the engines, where there are more than two, in two or three groups, one group being placed on each wing and the third, if there are three, in the center. If four engines are used, for exmmple, two may be placed on each wing, either in tandem or side by side, or one on each wing and two in the center. Both arrangements have been employed satisfactorily. In a very large airplane each group would consist of several engines and would have the continuous attention of a mechanic, who thus would not have to move all over the airplane.

Variations in Placement.

Although the arrangement just described is the commonest one, others have frequently been employed. The two extremes are represented by the commercial monoplane recently built by the Zeppelin Company at Staaken, having four separate engines distributed along the leading edge of the thick wing and completely housed inside the wing so that only the propellers project from bulges on the leading edge, and the giant airplanes built for the German army by the Linke-Hoffmann Company during the war. In the Linke-Hoffmanns, efficient weight distribution was neglected in favor of reliability and accessibility, the engines all being placed together in the body and being geared to drive a single enormous propeller (sometimes as much as 20 feet in diameter).

Finally, as to materials, the third point in which the large airplane appears to have some advantage, it is found that there are

some which are suited only for use in airplanes of considerable size, and the use of which becomes more and more profitable as the size becomes larger. This is notably the case with metals. It is almost impracticable to make a very small airplane of metal, and an all-metal airplane of minute size is certain to be heavier than if it had been built of wood. Among the very large airplanes, how ever, the advantage is distinctly the other way, and the aerial giant of the future is only likely to be realized by the fullest possible use of steel and aluminum. Another material which is familiar in the small airplane and which will probably disappear in the large one is the rubber in the shock absorbers. Rubber is very convenient for the absorption of light shocks, but when the weight to be handled reaches 10,000 lbs. or more, the landing shocks can be reduced and the landing gear simplified, while its reliability and length of service are improved at the same time by doing away with the rubber and substituting hydraulic shock absorbers, similar to those sometimes used on automobiles, backed by steel springs.